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THE STRESS CORROSION RESISTANCE AND THE CRYOGENIC TEMPERATURE MECHANICAL PROPERTIES OF ANNEALED NITRONIC 60 BAR MATERIAL

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16. ABSTRACT

This report presents the ambient and cryogenic temperature mechanical properties and the ambient temperature stress corrosion properties of annealed, straightened, and centerless ground Nitronic 60 stainless steel alloy bar material.

The mechanical properties of longitudinal specimens were evaluated at test temperatures from ambient to liquid hydrogen. The tensile test data indicated increasing strength with decreasing temperature to $-320^{\circ}F$ ($-196.0^{\circ}C$). Below liquid nitrogen temperature the smooth tensile and notched tensile strengths decreased slightly while the elongation and reduction of area decreased drastically. The Charpy V-notched impact energy decreased steadily with decreasing test temperature.

Stress corrosion tests were performed on longitudinal tensile specimens and transverse "C"-ring specimens exposed to: alternate immersion in a 3.5% NaCl bath; humidity cabinet; and a 5% salt spray atmosphere. The longitudinal tensile specimens experienced no corrosive attack. Approximately 3/4 of the transverse "C"-rings exposed to alternate immersion and to salt spray experienced a pitting attack on the top and bottom ends. The "C"-rings exposed to the humidity cabinet indicated only mild rusting.

Additional stress corrosion tests were performed on transverse tensile specimens which were machined from an annealed, straightened, and centerless ground 2.50- inch (6.35 cm) diameter bar. No failures occurred in the 90% stressed specimens exposed for 90 days in the alternate immersion and salt spray environments.

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SUMMARY

This report presents the ambient and cryogenic temperature mechanical properties and ambient temperature stress corrosion properties of annealed, straightened and centerless ground Nitronic 60 stainless steel bar material. Test specimens were manufactured from a 1.00-inch (2.54 cm) diameter bar.

The mechanical tests were performed at temperatures of 75°F (23.9°C), 0°F (-17.8°C), -100°F (-73.0°C), -200°F (-129.0°C), -320°F (-196.0°C) and -423°F (-252.8°C). These tests included smooth tensile (ultimate, yield, modulus, elongation and reduction of area), V-notched tensile (notched tensile strength and notched/unnotched tensile ratio) and Charpy V-notched impact. The test data indicate an increase in smooth and V-notched tensile properties with decreasing test temperature to -320°F (-196.0°C). Below liquid nitrogen temperature the ultimate tensile and the notched tensile strengths decreased, slightly, while the elongation and reduction of area dropped, drastically. From liquid nitrogen temperature to liquid hydrogen temperature the elongation and the reduction of area decreased from approximately 59% to 23% and 66% to 27%, respectively. The Charpy V-notched impact energy decreased steadily with decreasing test temperature yet remained above 120 ft-lbs (162.7 Joules) at -320°F (-196.0°C).

Results of the 180 day alternate immersion, humidity and salt spray tests on longitudinal tensile and transverse "C"-ring specimens, [machined from the 1.00-inch (2.54 cm) diameter bar], stressed to 50, 75, and 90% of the 0.2% yield strength, indicated that the alloy had excellent resistance to stress corrosion cracking when tested in the longitudinal direction. The design of the "C"-rings made them vulnerable to an end grain attack which caused pitting of more than 3/4 of the "C"-rings exposed to alternate immersion and salt spray environments. Metallographic examination of these pits revealed the branching phenomenon associated with stress corrosion cracking.

Additional tests were performed on transverse tensile specimens which were machined from an annealed, straightened, and centerless ground 2.50-inch (6.35 cm) diameter bar. Four specimens each were stressed to 90% of the 0.2% yield strength and exposed for 90 days to alternate immersion and to salt spray environments. No failures occurred in the corrosive atmospheres, however one specimen out of four, from each test, suffered from a corrosive attack that resulted in an approximate 30% degradation of the ultimate tensile strength and a much more severe degradation of the elongation and reduction of area properties. Improper machining of these two degraded tensile specimens contributed to the corrosive attack.

INTRODUCTION

Nitronic 60, an austenitic stainless steel developed by Armco Steel Company, is an alloy from a new family of stainless steels in which manganese and nitrogen are substituted for a portion of the usual nickel content. This Nitronic stainless was chosen for evaluation due to its high yield strength, good corrosion resistance and its excellent anti-galling properties. The alloy is reported to have good metal-to-metal abrasive resistance, excellent oxidation resistance, and excellent sub-zero impact strength. It is also slightly lighter than most stainless steels.

Nitronic 60 stainless steel contains approximately 17% chromium, 8.5% nickel, 8.0% manganese, 3.5% silicon, 0.07% carbon, and 0.1% nitrogen. The chemical composition of the 1.00-inch (2.54 cm) diameter bar and the 2.50-inch (6.35 cm) diameter bar materials shown in Table I were from Armco Steel Company's heat numbers 536288 and 656332, respectively, and were supplied in the annealed, straightened, and centerless ground condition.

EQUIPMENT AND MECHANICAL TEST SPECIMENS

The equipment used in the mechanical properties evaluation is described in a report by the author (Ref. 1). Tensile specimens, smooth and V-notched, are illustrated in Figures 1A and 1B, respectively. The charpy V-notched specimen configuration was in accordance with Federal Test Method Standard No. 151A Method 222.1.

STRESS CORROSION TEST PROCEDURE AND TEST SPECIMENS

The equipment and the test procedure used in the alternate immersion (A.I.) stress corrosion test is described in a report by Humphries (Ref. 2). The A.I. bath is a 3.5% NaCl solution maintained at a pH of 6.5 - 7.2, a temperature of 80°F ± 2°F (27°C ± 1°C), and a water purity per ASTM-D-1193-7 Type II. The A.I. cycle is 10 minutes in solution and 50 minutes out of solution. The salt spray test utilized the procedures of ASTM-B-117-64, "Standard Method of Salt Spray (Fog) Testing," which specifies a 5% salt solution at a pH of 6.5 - 7.2 and a temperature of 95°F (35°C). The humidity test was conducted in a cabinet maintained at 98% relative humidity and a temperature of 95°F (35°C).

The longitudinal tensile specimens and the transverse "C" - rings illustrated in Figure 1C were degreased with acetone, stressed to 50, 75, and 90% of the 0.2% yield strength then recleaned with acetone prior to the 180 day exposure in the corrosive environments. Unstressed tensile specimens were also exposed to the same environments.

Additional stress corrosion tests were performed on transverse tensile specimens which were machined from an annealed, straightened, and centerless ground 2.50- inch (6.35 cm) diameter bar. Four specimens each were stressed to 90% of the 0.2% yield strength and exposed for 90 days to alternate immersion and to salt spray environments.

RESULTS AND DISCUSSION

1. Mechanical Properties Evaluation

The tensile test results of the ambient through cryogenic temperature mechanical properties evaluation and the charpy V-notched impact data are tabulated in Tables II and III, respectively. These properties are also plotted in Figures 2-3.

Table II contains test data on annealed, straightened, and centerless ground bar material tensile specimens. These tensile test data indicate an increase in ultimate tensile and 0.2% yield strengths with decreasing temperature from ambient to -320°F (-196.0°C). At liquid hydrogen temperature there was a slight decrease in ultimate tensile strength. The elongation (percent in 4 diameters) and reduction of area indicated excellent ductility from ambient to -320°F (-196.0°C). At liquid hydrogen temperature there was an approximate 65% loss in elongation and 66% loss in reduction of area, as compared to ambient temperature properties. However, this loss in ductility is evidently not detrimental to the material since it still retains acceptable properties at LH_2 temperature. The actual fracture strength (fracture load divided by area at fracture) increased rapidly with decreasing temperature from ambient to -320°F (-196.0°C). At liquid hydrogen temperature there was a drastic loss in fracture strength. The notched/unnotched (N/U) tensile ratios (average $K_t = 7.0$) remained above 1.20 from ambient to liquid hydrogen temperature, indicating excellent notched tensile properties.

Table III indicates a steady decrease in charpy V-notched impact energy with decreasing temperature, yet the impact energy remained above 120.0 ft-lbs (162.7 Joules) at -320°F (-196.0°C). The ambient temperature impact energy exceeded 240.0 ft-lbs (325.4 Joules) for 3 of the 5 tests with the lowest value being 214.0 ft-lbs (290.1 Joules). This inconsistency can be attributed to the annealed bar being straightened and centerless ground. The straightening process induced a certain amount of work into the bar and this work was not uniformly distributed. This work hardening variable is reflected in the inconsistent impact energies.

2. Metallography of As Received Bar Material

Figures 4 and 5 show the microstructure of the longitudinal and transverse directions, respectively. The stringer material shown in the longitudinal microstructure was analyzed by Energy Dispersive Analysis of X-rays (EDAX) and found to contain the deoxidation additives, Aluminum and Calcium. The grains are free from any precipitated carbides and there is no evidence of banding.

3. Stress Corrosion Evaluation

Table IV contains test data prior to and after 180 days exposure to the following environments:

(1) Alternate Immersion - 3.5% NaCl Bath 80°F (27°C)

(2) Humidity Cabinet - 95°F (35°C) 98% Relative Humidity

(3) Salt Spray Cabinet - 5.0% NaCl Fog 95°F (35°C)

These data indicate that the longitudinal tensile specimens were not susceptible to stress corrosion cracking, even when stressed to 90% of the 0.2% yield strength and exposed for 180 days to the environments listed above.

Figure 6 illustrates typical tensile and "C" - ring specimens stressed to 90% of the 0.2% yield strengths and exposed to the corrosive environments for 180 days.

Although there was no corrosive attack in any of the longitudinal tensile specimens exposed to the above listed environments, there was some pitting corrosion on the top and bottom ends of approximately 3/4 of the "C" - ring specimens exposed to the alternate immersion and to the salt spray environments. The design of the "C" - rings made them vulnerable to the end grain attack. Even though there was extensive pitting on these specimens there were no actual failures. (Armco Steel Company has reported similar surface pitting on specimens exposed to quiet sea water environment, however, this environment also attacked 316L and 304 stainless steel to a greater degree.) The transverse "C" - rings exposed to the humidity cabinet environment experienced only a light coating of rust in isolated areas.

a. Metallography of Corroded "C" - Rings

Figure 7 illustrates the resultant stress corrosion attack caused by the end grain surface pitting. The "C" - ring specimen shown in Figure 7 was stressed to 90% of the 0.2% yield strength and exposed for 180 days to the A.I. bath. Minute cracks and pitting began in this "C" - ring after approximately two months exposure.

Figure 8 shows the stress corrosion attack on a "C" - ring specimen which was stressed to 90% of the 0.2% yield strength and exposed for 180 days to the salt spray. After approximately four months exposure these "C" - rings experienced pitting and cracking.

3. Stress Corrosion Evaluation (Cont'd)

b. Transverse Tensile Specimens

Additional stress corrosion tests were performed on transverse tensile specimens which were machined from an annealed, straightened, and centerless ground 2.50-inch (6.35 cm) diameter bar. No failures occurred in the 90% stressed specimens exposed for 90 days in the alternate immersion and salt spray environments. Improper machining of the tensile specimen gage length contributed to the corrosive attack on one of four specimens exposed to each environment. This corrosive attack produced an approximate 30% loss in ultimate tensile strength when tested after 90 days exposure.

Figure 9 shows the machining grooves along the gage length of the specimen (A) which had been exposed to the A.I. environment. These grooves were present prior to the tensile test and could have produced a crevice type corrosion. The resulting tensile properties are shown in Table V.

Figure 10 shows machining imperfections along the gage length of the specimen (H) which had been exposed to the salt spray environment. These imperfections could have attributed to the corrosive attack which is also illustrated in Figure 10. The resulting tensile properties are shown in Table V.

CONCLUSIONS

Based upon the results of this evaluation of Nitronic 60 stainless steel annealed and straightened bar material specimens, the following conclusions are drawn:

(1) The ultimate tensile and 0.2% yield strengths of the longitudinal tensile specimens increased with decreasing test temperature to liquid nitrogen temperature.

(2) The elongation (percent in 4 diameters) and reduction of area indicated excellent ductility from ambient to $-320^{\circ}F$ ($-196.0^{\circ}C$).

(3) The actual fracture strength increased rapidly with decreasing temperature from ambient to $-320^{\circ}F$ ($-196.0^{\circ}C$).

(4) The notched to unnotched tensile ratios ($K_t = 7.0$) remained above 1.20 from ambient to liquid hydrogen temperature.

(5) Charpy V-notched impact energy decreased with decreasing temperature, yet remained above 120.0 ft-lbs (162.7 Joules) at $-320^{\circ}F$ ($-196.0^{\circ}C$).

(6) Considering the overall mechanical properties obtained in this evaluation, Nitronic 60 stainless steel alloy bar in the annealed condition could be utilized in tension applications from ambient to liquid hydrogen temperature. Although there is a considerable decrease in ductility at liquid hydrogen temperature, the material is considered suitable for use at that temperature.

(7) Nitronic 60 stainless steel annealed bar material, as tested in this program, is not susceptible to stress corrosion cracking in the longitudinal direction, even when stressed to 90% of the 0.2% yield strength and exposed to 180 days of moisture and chloride environments.

(8) Transverse "C"-ring specimens exposed to alternate immersion and to the salt spray experienced a pitting attack after approximately two months exposure regardless of the stress level. Metallographic examination of these surface pits after 180 days of exposure revealed the branching phenomenon associated with stress corrosion cracking.

(9) Additional stress corrosion tests performed on transverse tensile specimens stressed to 90% of yield strength and exposed for 90 days to A.I. and salt spray produced no failures. Corrosive attack on two of these specimens could be attributed to improper machining of the gage lengths.

(10) Considering the overall stress corrosion data obtained in this evaluation, Nitronic 60 stainless steel alloy bars [1.00-inch (2.54 cm) and 2.50-inch (6.35 cm) diameters] in the annealed condition could be utilized in applications where 300 series stainless corrosion resistance is needed, yet additional strength is required.

REFERENCES

1. Montano, J. W.: "A Mechanical and Stress Corrosion Evaluation of Custom 455 Stainless Steel Alloy," TMX-64682, August 2, 1972.

2. Humphries, T. S.: "Procedures for Externally Loading and Corrosion Testing Stress Corrosion Specimens," TMX-53483, June 29, 1966.

TABLE I

CHEMICAL COMPOSITION OF NITRONIC 60 STAINLESS STEEL ALLOY BARS

Analysis	Fe	Cr	Mn	Ni	Si	C	P	S	N	Other Elements
Nominal	Main.	16-18	7-9	8-9	3.5-4.5	.10 Max	—	—	.08-.18	—
Armco	Main.	16.98	8.11	8.38	3.90	0.074	0.016	0.006	—	0.11
MSFC	Main.	16.80	7.94	8.37	3.53	0.071	0.018	0.006	0.096	—

Armco Heat No. 536288 for 1.00 Inch (2.54 cm) Diameter Bar.

Armco	Main.	16.85	8.43	8.62	4.00	.071	—	—	0.12	—

Armco Heat No. 656332 for 2.50 Inch (6.35 cm) Diameter Bar.

TABLE II

LOW TEMPERATURE MECHANICAL PROPERTIES OF NITRONIC 60 STAINLESS STEEL LONGITUDINAL TENSILE SPECIMENS

0.250 INCH (0.635 CM) DIAMETER - MACHINED FROM A 1.00 INCH (2.54 CM) DIAMETER ANNEALED AND STRAIGHTENED BAR

Test Temperature °F	(°C)	Ultimate Tensile Strength KSI	(GN/m^2)	.2% Offset Yield Strength KSI	(GN/m^2)	Elongation 1.00-In (2.54 cm) 4D%	Reduction of Area %	Fracture Strength KSI	(GN/m^2)	Modulus $X10^{-6}$ PSI	(GN/m^2)	N/U* Tensile Ratio	No. of Tests
75	(+23.9)	109.3	(0.754)	58.1	(0.400)	66.4	79.0	336.1	(2.317)	24.0	(0.165)	1.44	4
0	(-17.8)	128.1	(0.883)	67.3	(0.464)	71.3	79.7	433.4	(2.988)	23.7	(0.163)	1.37	4
-100	(-73.0)	148.4	(1.023)	77.9	(0.537)	70.5	80.9	447.1	(3.083)	24.2	(0.167)	1.45	4
-200	(-129.0)	167.6	(1.156)	87.4	(0.603)	62.4	78.4	457.0	(3.151)	24.2	(0.167)	1.46	4
-320	(-196.0)	217.9	(1.502)	101.4	(0.699)	59.5	65.8	594.0	(4.095)	24.8	(0.171)	1.26	4
-423	(-252.8)	203.8	(1.405)	125.3	(0.864)	23.5	26.6	277.6	(1.914)	24.8	(0.171)	1.33	4

* Average Stress Concentration Factor $K_t = 7.0$

TABLE III

LOW TEMPERATURE IMPACT ENERGY OF NITRONIC 60 STAINLESS STEEL
CHARPY V-NOTCHED IMPACT SPECIMENS PER FEDERAL TEST METHOD STD. NO. 151
MACHINED FROM A 1.00-INCH (2.54 CM) DIAMETER BAR

Test Temperature °F	(°C)	Charpy V-Notched Impact Energy Ft - Lb	(Joules)
75	(+23.9)	>240.0	>325.4
		>240.0	>325.4
		>240.0	>325.4
		221.0	299.6
		214.0	290.1
	Avg.	231.0	309.9
0	(-17.8)	220.0	298.3
		218.0	295.6
		216.5	293.5
		207.5	281.3
	Avg.	215.5	292.2
-100	(-73.0)	214.5	290.8
		199.0	269.8
		194.0	263.0
		181.0	245.4
	Avg.	197.1	267.2
-200	(-129.0)	173.0	234.6
		172.5	233.9
		172.5	233.9
		164.0	222.3
	Avg.	170.5	231.2
-320	(-196.0)	148.0	200.6
		145.0	196.6
		141.0	191.2
		134.5	182.3
		124.0	168.1
	Avg.	138.5	187.8

TABLE IV

MECHANICAL PROPERTIES OF NITRONIC 60 STAINLESS STEEL LONGITUDINAL TENSILE SPECIMENS
0.1250 INCH (0.3175 CM) DIAMETER — MACHINED FROM A 1.00 INCH (2.54 CM) DIAMETER ANNEALED AND STRAIGHTENED BAR
[EXPOSED TO VARIOUS ENVIRONMENTS]

Exposure Time Days	Applied Stress Percent of Yield Strength	Ultimate Tensile Strength KSI	Ultimate Tensile Strength (GN/m^2)	0.2% Offset Yield Strength KSI	0.2% Offset Yield Strength (GN/m^2)	Elongation 0.5-In. (1.27 cm) 4D%	Reduction of Area %	Fracture Strength KSI	Fracture Strength (GN/m^2)	Modulus $X10^{-6}$ PSI	Modulus $X10^{-6}$ (GN/m^2)	Number of Tests
				As Received Mechanical Properties								
0	0	115.9	(0.799)	71.3	(0.492)	83.1	76.0	335.9	(2.316)	25.8	(0.178)	4
				Alternate Immersion - 3.5 Percent NaCl Bath 80°F (27°C)								
180	0	115.8	(0.798)	71.2	(0.491)	83.2	75.3	345.5	(2.382)	26.3	(0.181)	3
180	50	115.7	(0.798)	70.3	(0.485)	82.1	75.8	337.3	(2.326)	26.7	(0.184)	4
180	75	114.3	(0.788)	73.7	(0.508)	81.5	76.3	335.2	(2.311)	25.3	(0.174)	3
180	90	114.7	(0.791)	73.0	(0.503)	82.0	78.2	355.5	(2.451)	24.5	(0.169)	4
				Salt Spray Cabinet 95°F (35°C)								
180	0	114.5	(0.789)	70.0	(0.483)	81.0	77.4	346.9	(2.392)	24.7	(0.170)	3
180	50	115.3	(0.795)	71.2	(0.491)	82.0	76.0	333.6	(2.300)	25.6	(0.176)	4
180	75	115.1	(0.794)	74.5	(0.514)	81.8	75.1	336.2	(2.318)	25.4	(0.175)	3
180	90	114.7	(0.791)	73.3	(0.505)	81.1	76.1	337.9	(2.330)	25.7	(0.177)	4
				Humidity Cabinet 95°F (35°C) 98% R.H.								
180	0	114.3	(0.788)	67.2	(0.463)	82.6	76.6	340.1	(2.345)	25.0	(0.172)	4
180	50	114.7	(0.791)	70.9	(0.489)	81.6	76.3	337.9	(2.330)	25.2	(0.174)	3
180	75	114.9	(0.792)	71.9	(0.496)	82.0	76.4	343.4	(2.368)	24.6	(0.170)	4
180	90	114.4	(0.789)	73.9	(0.509)	82.6	76.0	339.4	(2.340)	24.9	(0.172)	4

TABLE V

MECHANICAL PROPERTIES OF NITRONIC 60 STAINLESS STEEL TRANSVERSE TENSILE SPECIMENS
0.1250 INCH (0.3175 CM) DIAMETER – MACHINED FROM A 2.50 INCH (6.35 CM) DIAMETER ANNEALED AND STRAIGHTENED BAR
STRESSED TO 90% OF YIELD STRENGTH AND EXPOSED TO CORROSIVE ENVIRONMENTS FOR 90 DAYS

Specimen Number		Ultimate Tensile Strength KSI	Ultimate Tensile Strength (GN/m^2)	0.2% Offset Yield Strength KSI	0.2% Offset Yield Strength (GN/m^2)	Elongation 0.5-In. (1.27 cm) 4D%	Reduction of Area %	Fracture Strength KSI	Fracture Strength (GN/m^2)	Modulus $X10^{-6}$ PSI	Modulus $X10^{-6}$ (GN/m^2)
As Received Mechanical Properties[1]											
1		117.8	(0.812)	62.6	(0.432)	78.0	79.1	489.6	(3.376)	26.0	(0.179)
2		115.1	(0.793)	60.3	(0.416)	79.5	—	—		25.2	(0.174)
	Avg	116.4	(0.802)	61.4	(0.423)	78.7				25.6	(0.176)
Alternate Immersion - 3.5% NaCl Bath 80°F (27°C)											
A*		* 78.7	(0.543)	*58.2	(0.401)	*~4.5	*36.7	*113.2	(0.780)	*25.3	(0.174)
B		115.2	(0.794)	62.2	(0.429)	69.5	62.6	272.1	(1.876)	24.1	(0.166)
C		112.5	(0.776)	61.2	(0.422)	83.0	66.7	292.5	(2.017)	26.8	(0.185)
D		112.5	(0.776)	60.2	(0.415)	86.0	66.7	297.5	(2.051)	27.1	(0.187)
	Avg *(Exclude #A)	113.4	(0.782)	61.2	(0.422)	79.5	65.3	287.4	(1.982)	26.0	(0.179)
	* % Loss from Avg	30.6%		4.9%		94.3%	43.9%	60.6%		—	
Salt Spray Cabinet 95°F (35°C)											
E		112.5	(0.776)	62.3	(0.429)	78.0	51.7	217.2	(1.497)	26.9	(0.185)
F		111.1	(0.766)	61.0	(0.420)	81.5	53.3	222.8	(1.536)	25.5	(0.176)
H*		* 79.2	(0.546)	*56.4	(0.389)	*~4.0	*33.0	—	—	*26.1	(0.180)
N		111.8	(0.771)	60.3	(0.416)	82.0	65.6	279.3	(1.926)	26.2	(0.181)
	Avg *(Exclude #H)	111.8	(0.771)	61.2	(0.422)	80.5	56.8	239.8	(1.653)	26.2	(0.181)
	* % Loss from Avg	29.2%		7.8%		95.0%	41.8%	—		—	

Armco Heat No. 656332

[1] As Received Mechanical Property Determination made on 0% Stressed and 0% Exposed Specimens.

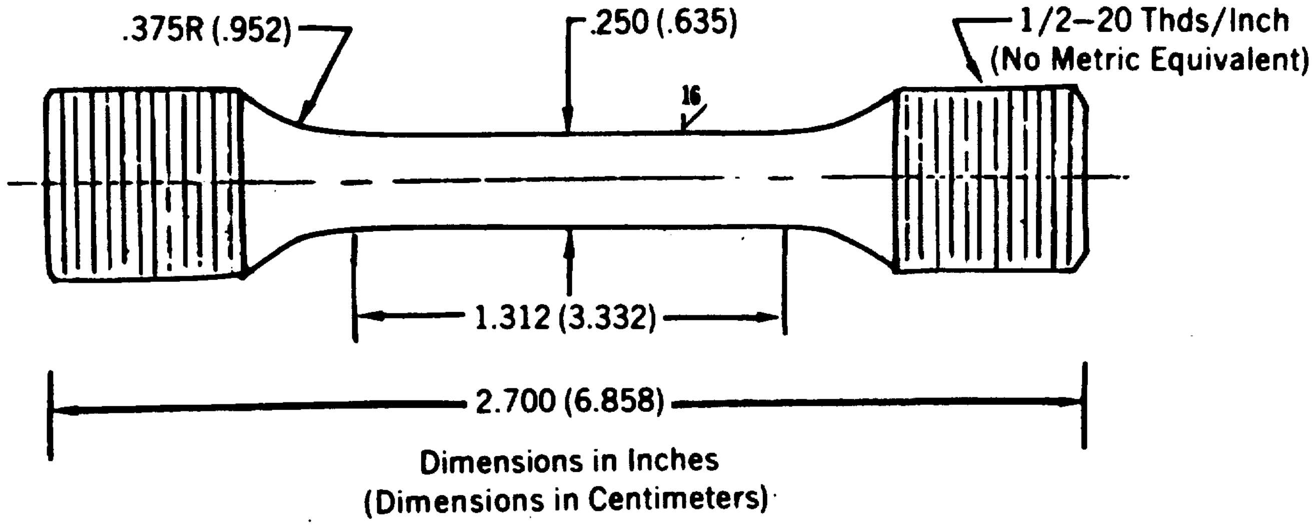


FIGURE 1A - SMOOTH TENSILE SPECIMEN CONFIGURATION

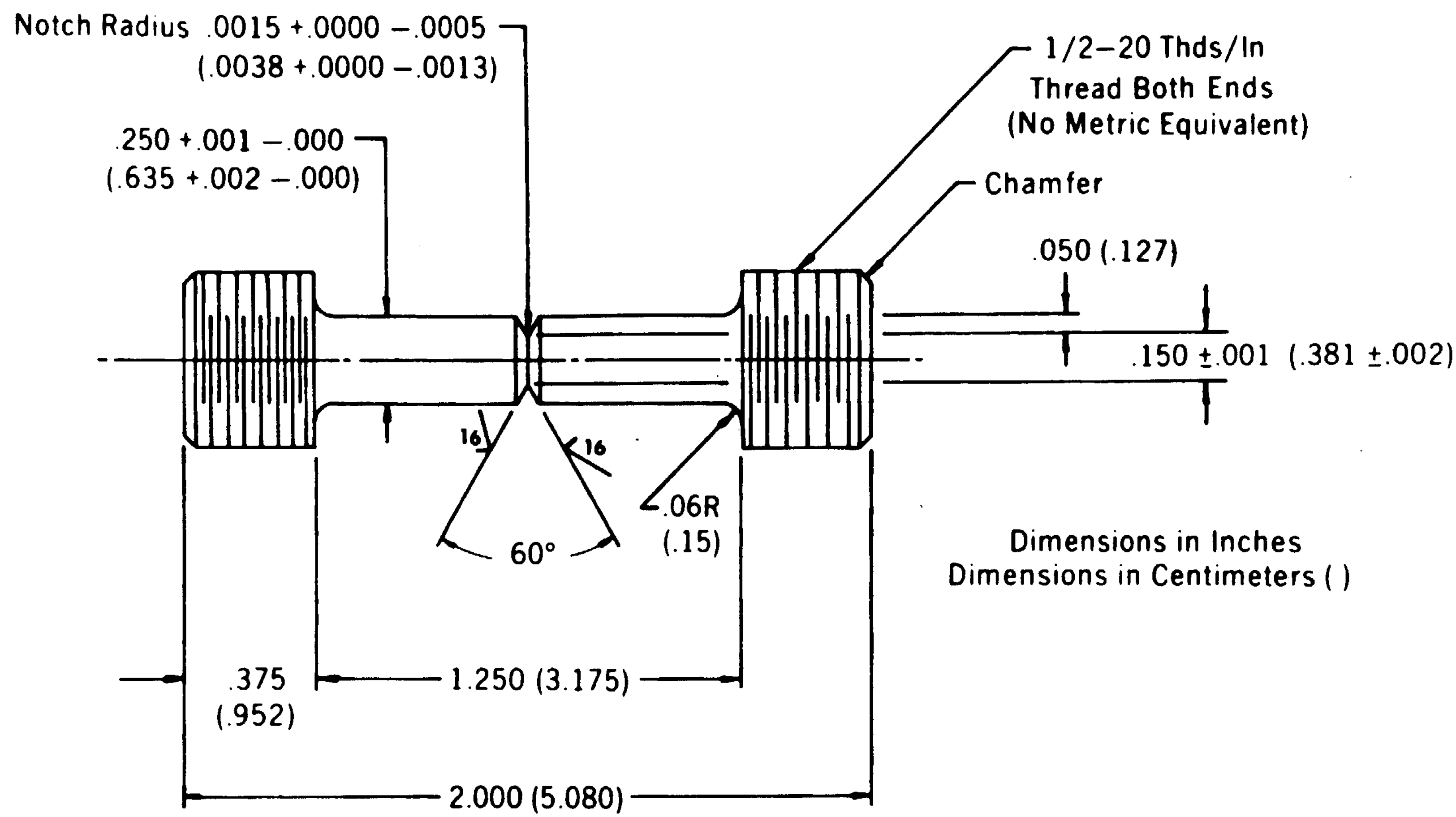
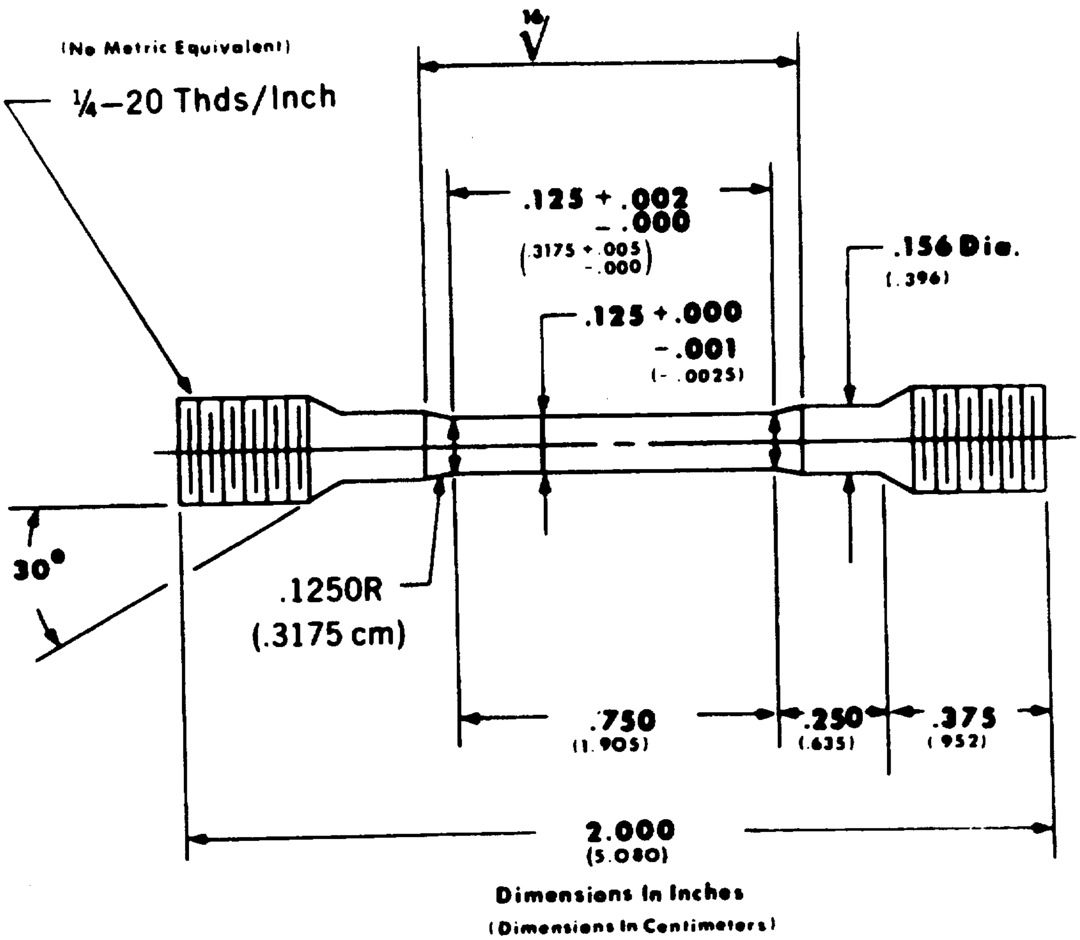


FIGURE 1B · V—NOTCHED TENSILE SPECIMEN CONFIGURATION



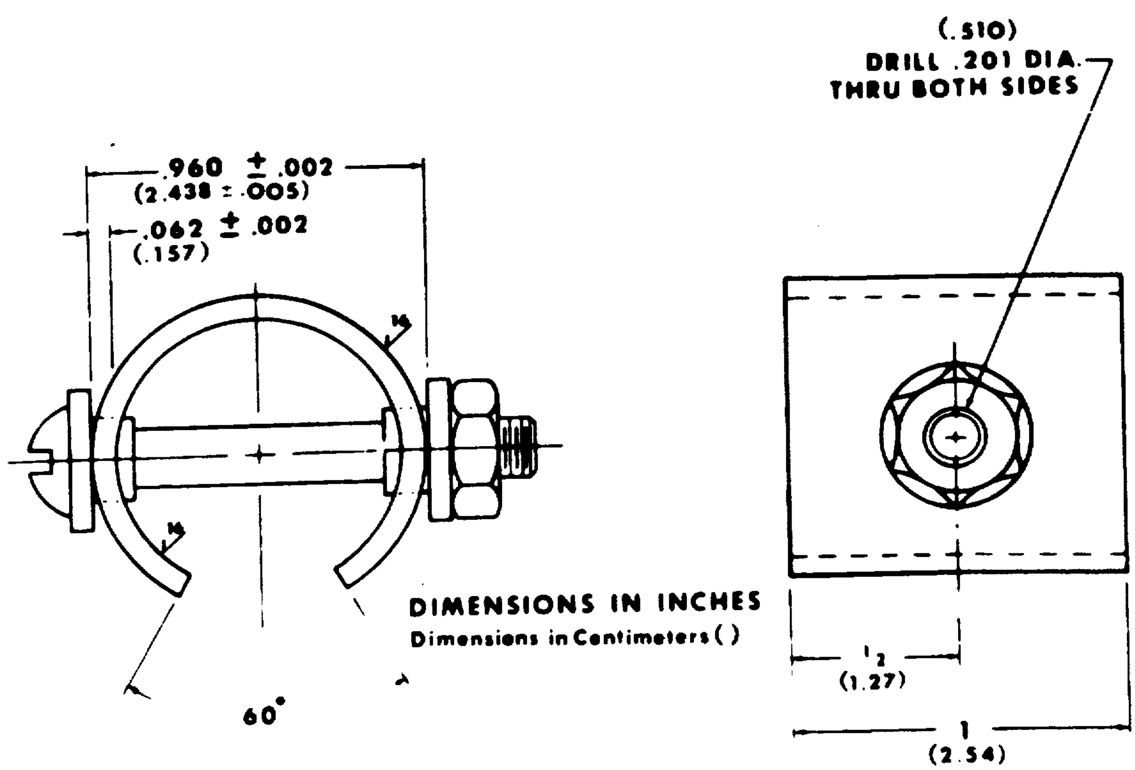


FIGURE 1C - STRESS CORROSION TEST SPECIMEN CONFIGURATIONS

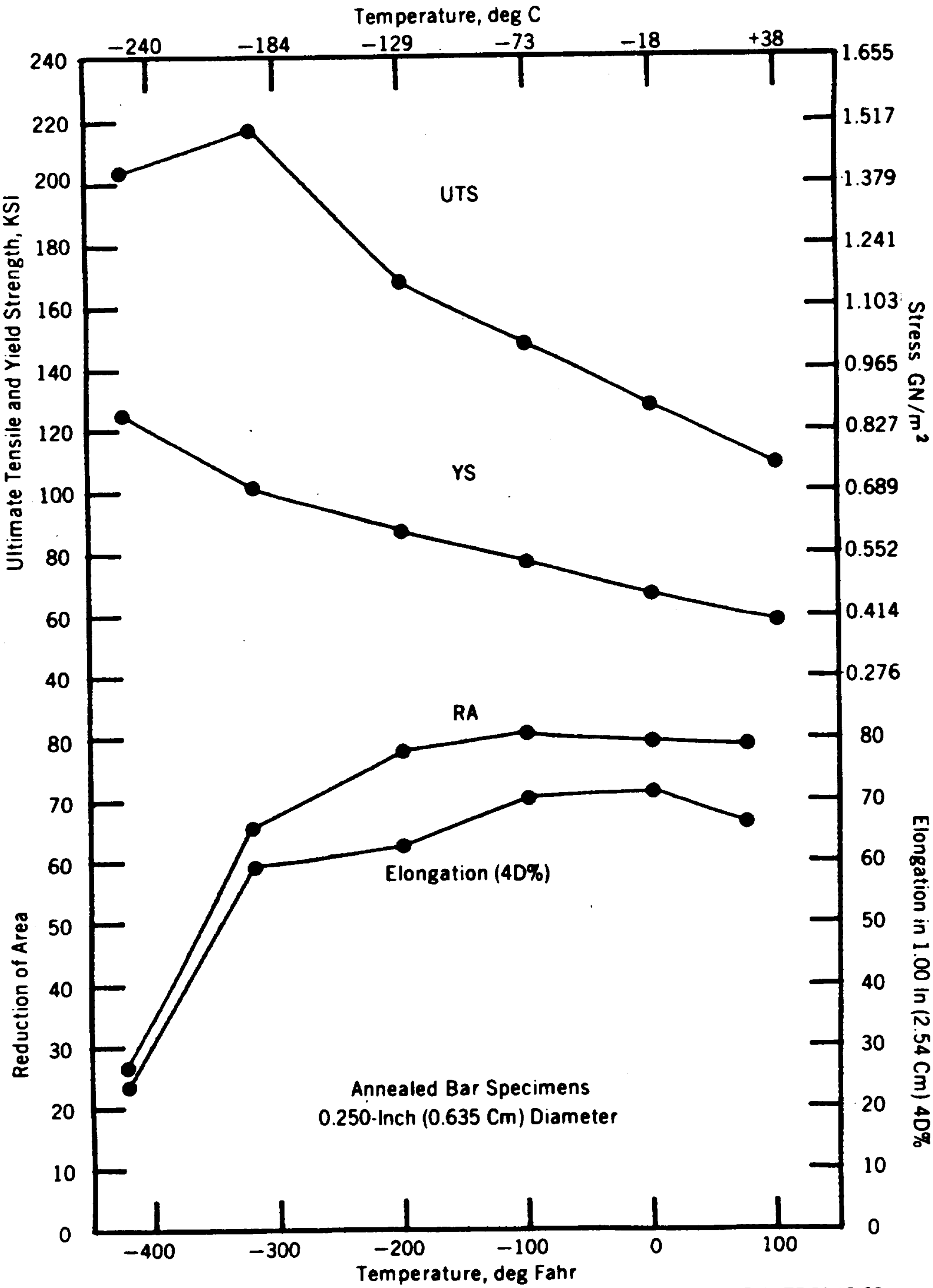


FIGURE 2 · LOW TEMPERATURE MECHANICAL PROPERTIES OF ANNEALED NITRONIC 60 STAINLESS STEEL SPECIMENS MACHINED FROM A 1.00 INCH (2.54 CM) DIAMETER BAR

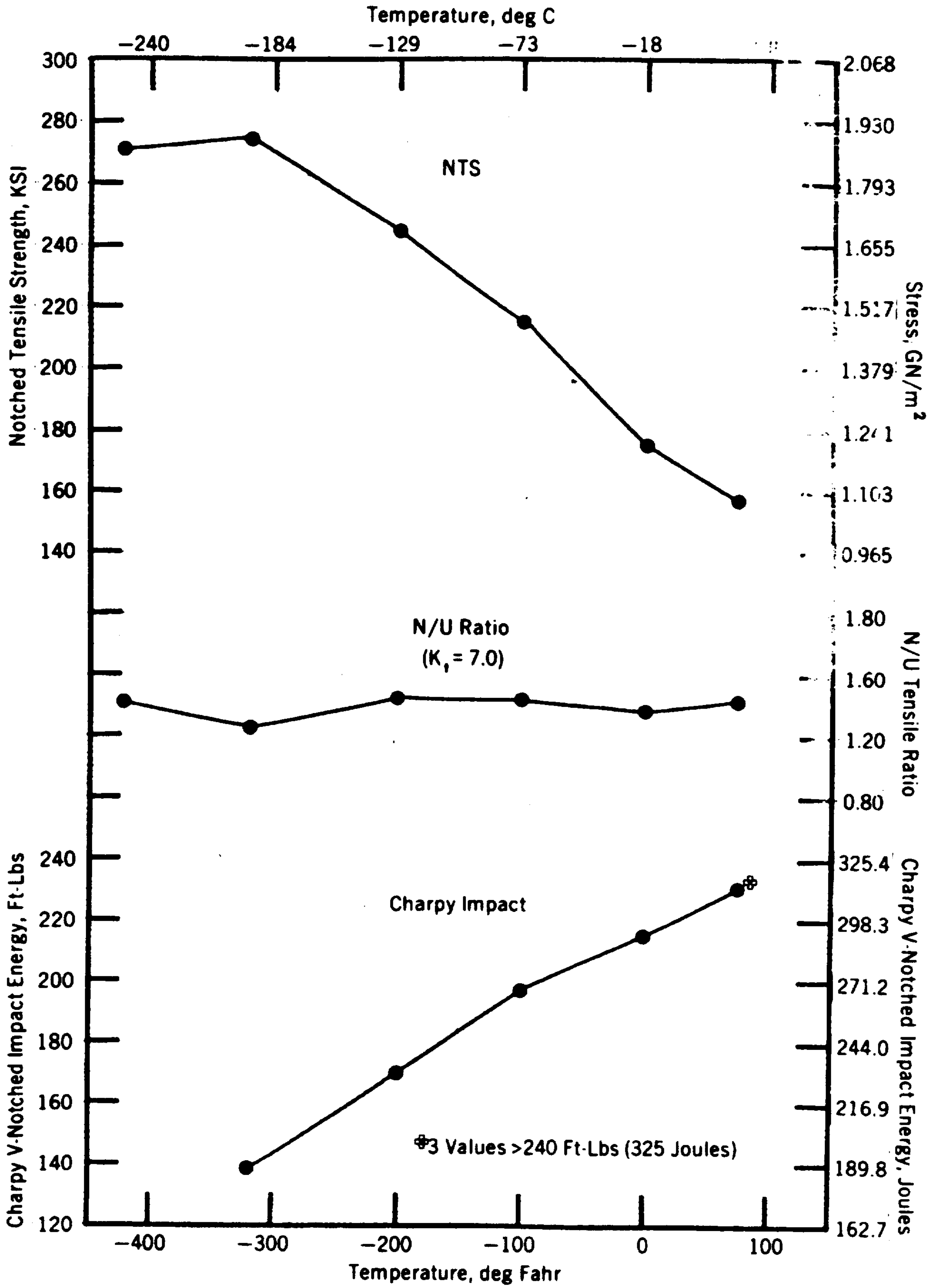


FIGURE 3 - LOW TEMPERATURE NOTCHED PROPERTIES OF ANNEALED NITRONIC 60 STAINLESS STEEL BAR SPECIMENS

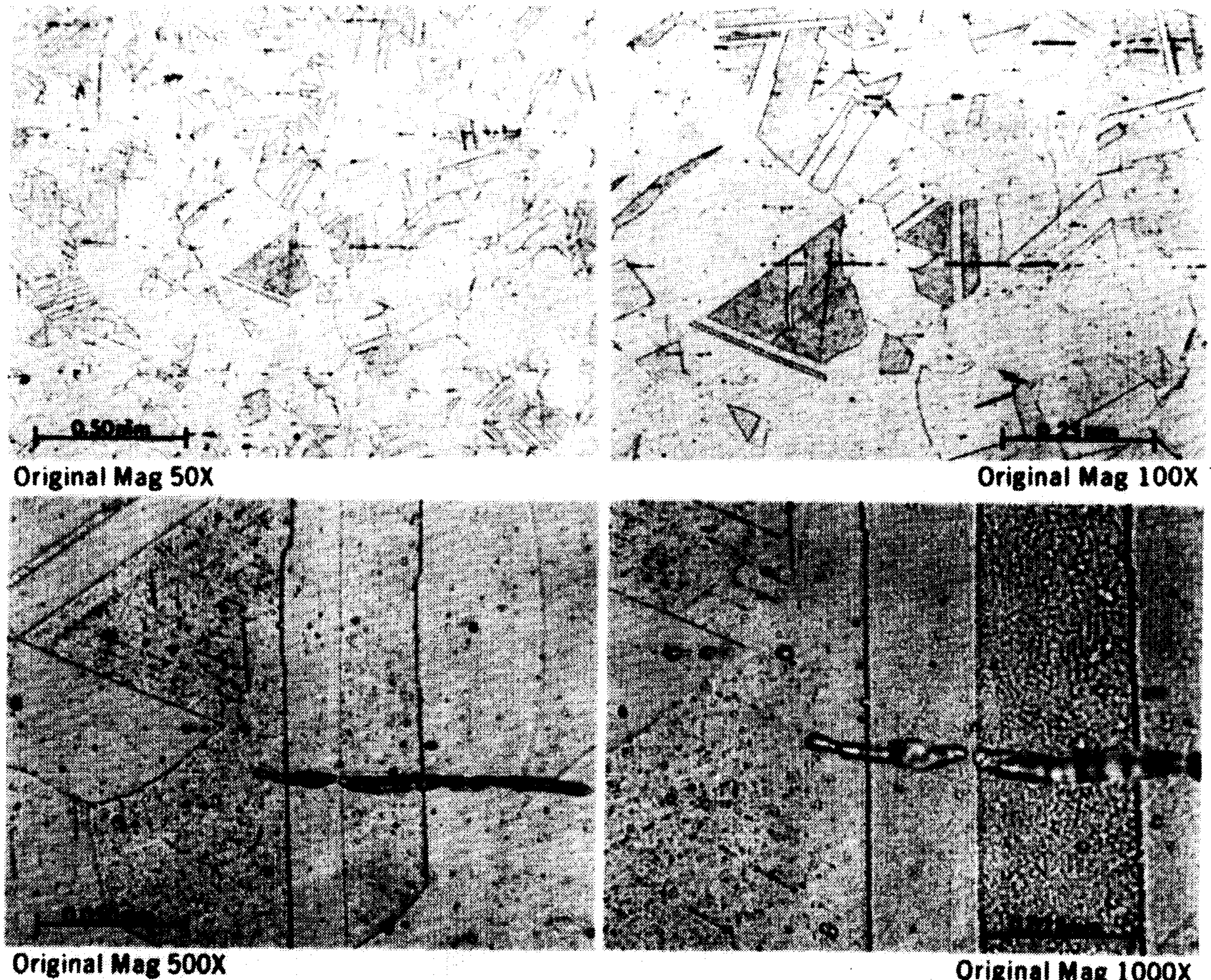
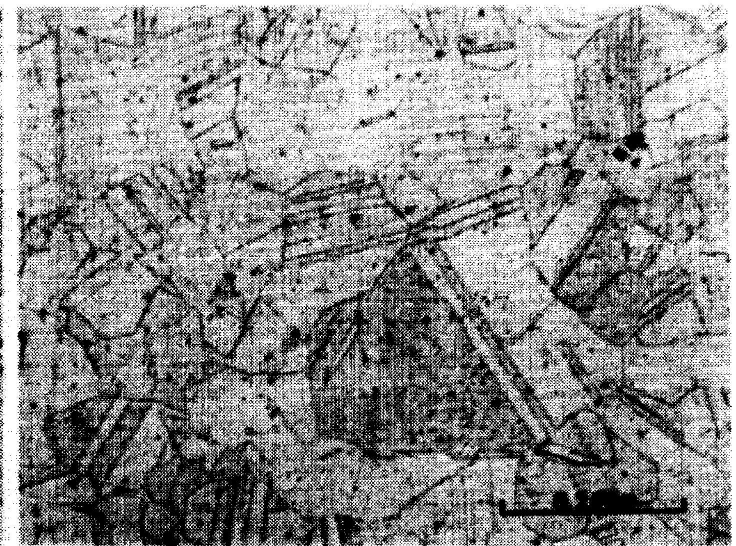
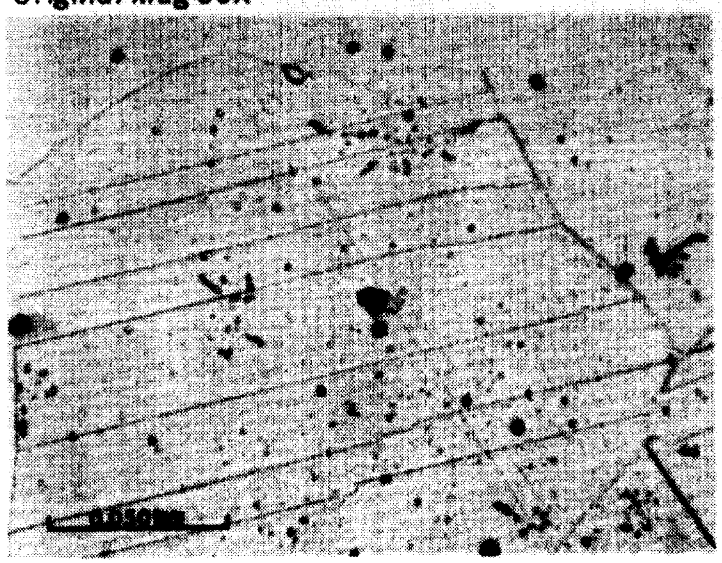


FIGURE 4 - LONGITUDINAL MICROSTRUCTURE OF ANNEALED NITRONIC 60 STAINLESS STEEL BAR
Etchant : Nitric 10 ml + Hydrocholoric 15 ml + Acetic 10 ml + Glycerol 5 ml

Original Mag 50X



Original Mag 100X

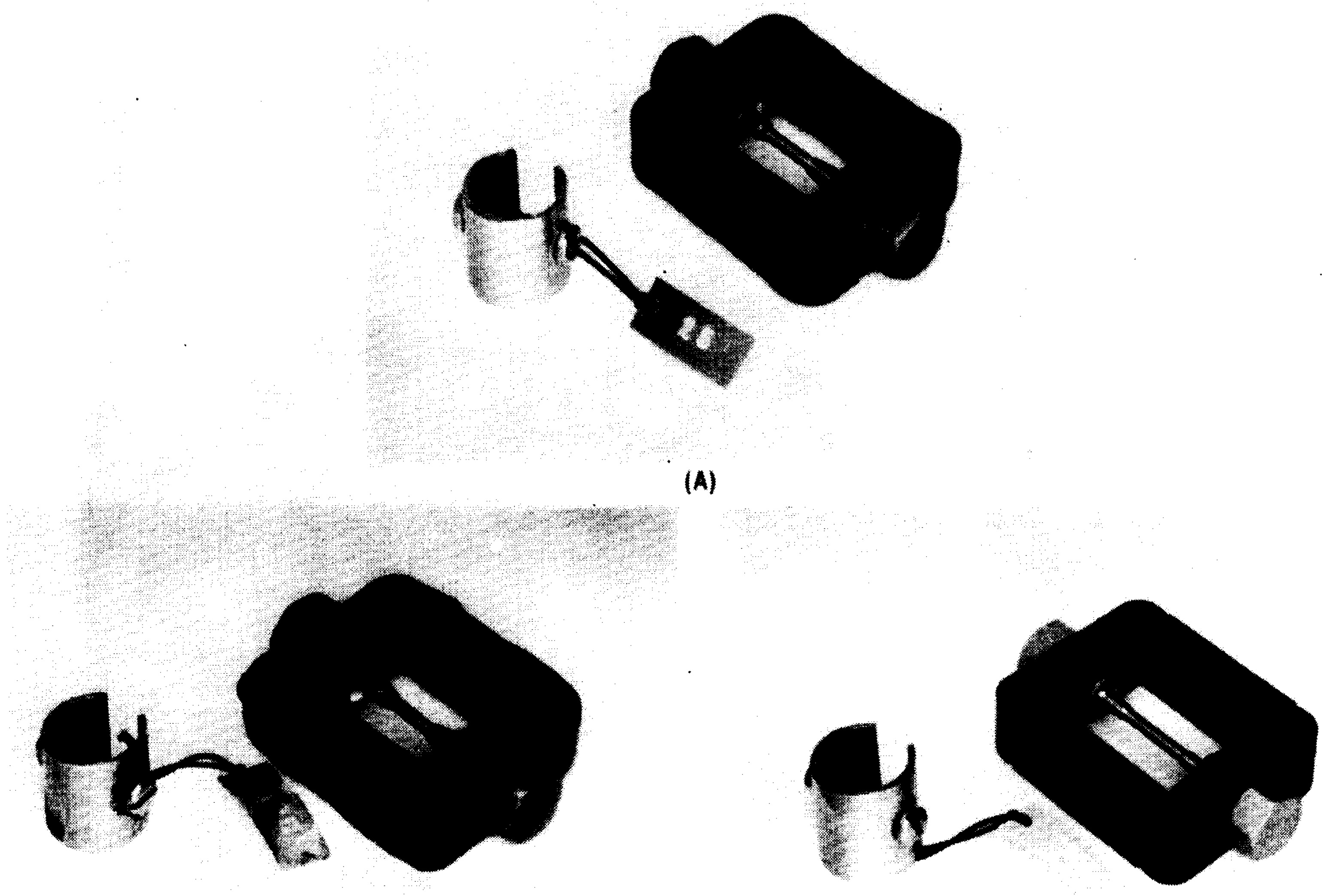


Original Mag 500X

Original Mag 1000X

FIGURE 5 - TRANSVERSE MICROSTRUCTURE OF ANNEALED NITRONIC 60 STAINLESS STEEL BAR

Etchant : Nitric 10 ml + Hydrochloric 15 ml + Acetic 10 ml + Glycerol 5 ml



(A)

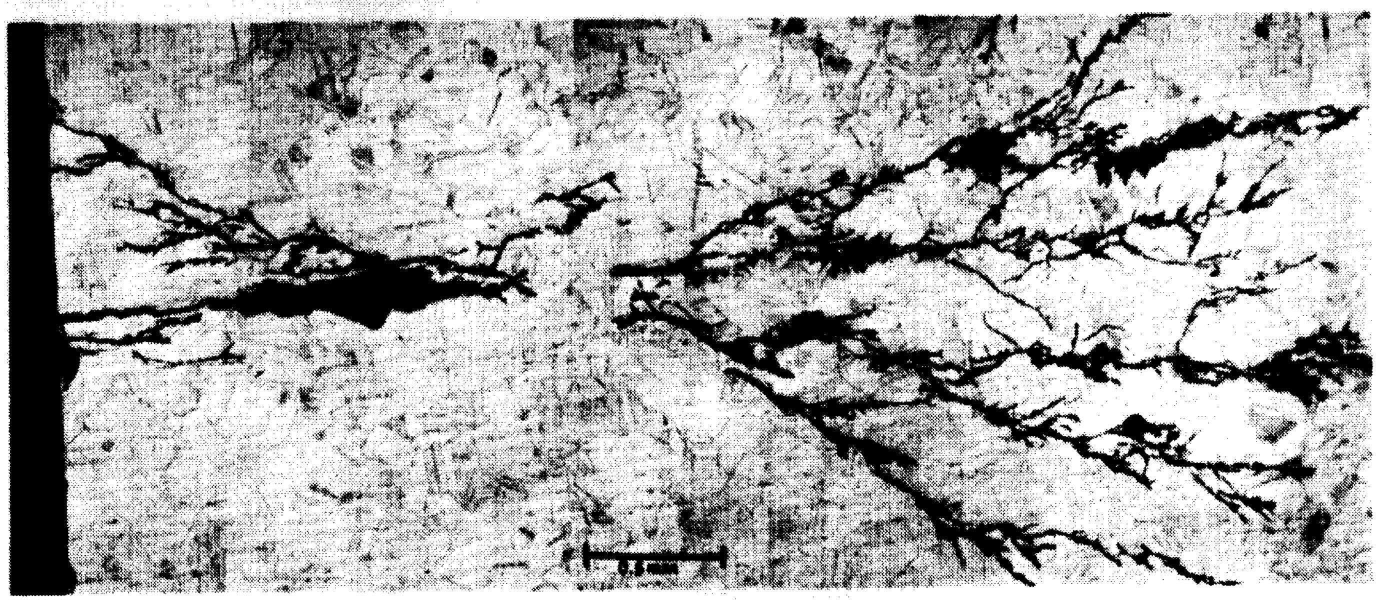
(B)

(C)

FIGURE 6 · NITRONIC 60 STAINLESS STEEL STRESS CORROSION SPECIMENS STRESSED TO 90% OF YIELD STRENGTH AND EXPOSED FOR 180 DAYS TO (A) ALTERNATE IMMERSION, (B) SALT SPRAY, (C) HUMIDITY ENVIORNMENTS

ETCHED ORIGINAL MAG 50X

UNETCHED ORIGINAL MAG 30X

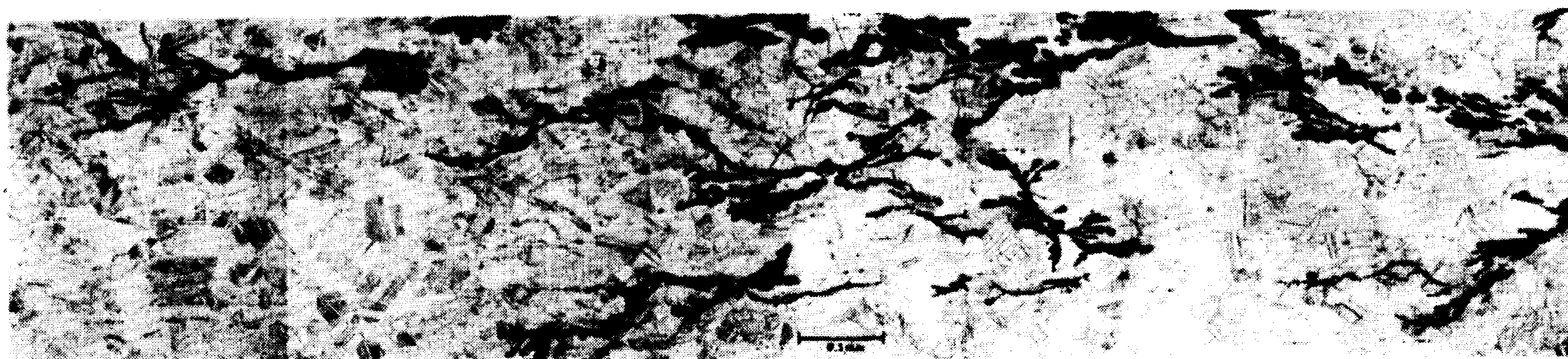


ETCHANT : MIXED ACIDS IN GLYCEROL ORIGINAL MAG 50X

FIGURE 7 - MICROSTRUCTURE OF NITRONIC 60 STAINLESS STEEL 'C'-RING AFTER 180 DAYS OF ALTERNATE IMMERSION STRESSED TO 90% OF YIELD STRENGTH

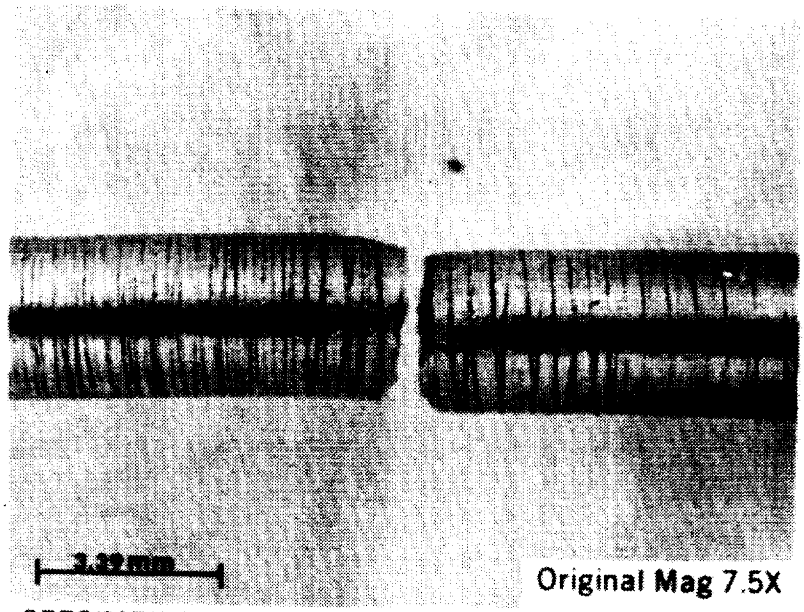
ETCHED ORIGINAL MAG 50X

UNETCHED ORIGINAL MAG 30X

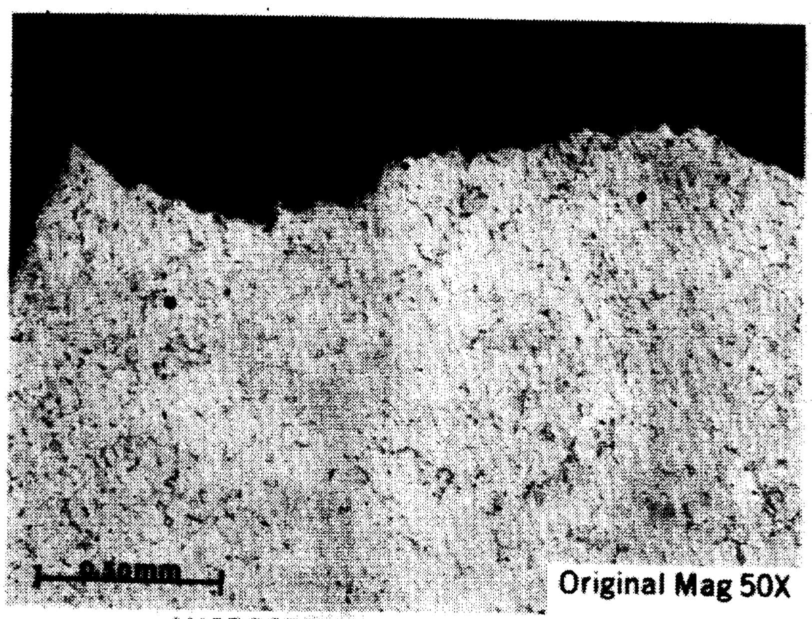


ETCHANT : MIXED ACIDS IN GLYCEROL ORIGINAL MAG 50X

FIGURE 8 - MICROSTRUCTURE OF NITRONIC 60 STAINLESS STEEL 'C' RING AFTER 180 DAYS OF SALT SPRAY STRESSED TO 90% OF YIELD STRENGTH



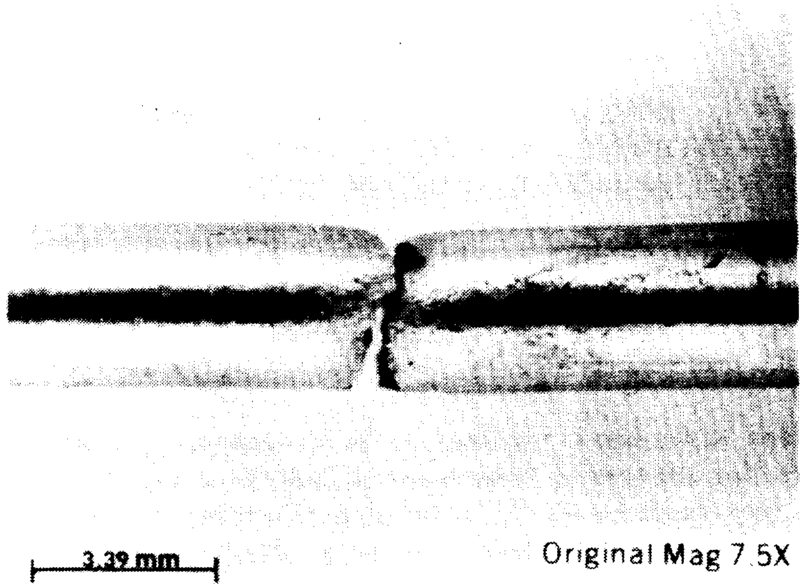
SPECIMEN SURFACE CONDITION AFTER TENSILE TEST



MICROSTRUCTURE AT FRACTURE

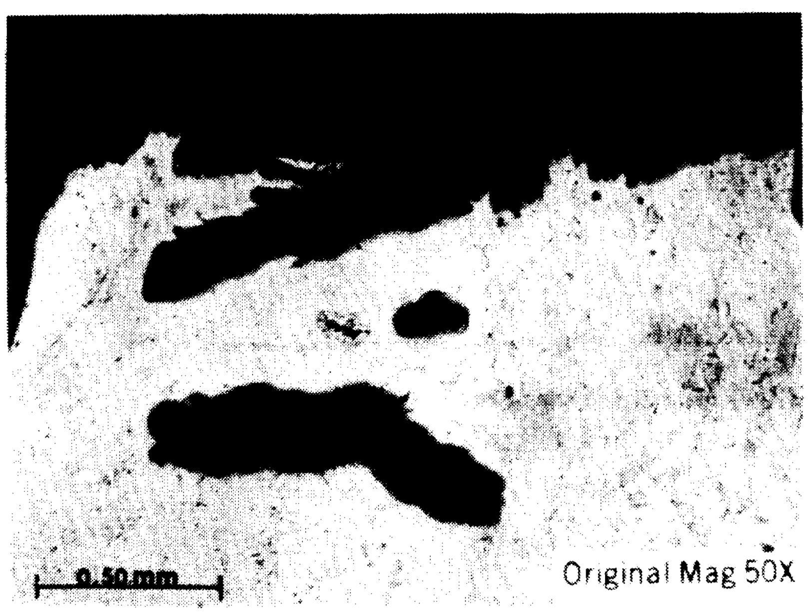
Etchant : Mixed Acids in Glycerol

FIGURE 9 - NITRONIC 60 STAINLESS STEEL TRANSVERSE TENSILE SPECIMEN AFTER 90 DAYS OF A.I. (3.5% NACL) — STRESSED TO 90% OF YIELD STRENGTH



Original Mag 7.5X

SPECIMEN SURFACE CONDITION AFTER TENSILE TEST



MICROSTRUCTURE AT FRACTURE

Etchant : Mixed Acids in Glycerol

FIGURE 10 · NITRONIC 60 STAINLESS STEEL TRANSVERSE TENSILE SPECIMEN AFTER 90 DAYS OF SALT SPRAY – STRESSED TO 90% OF YIELD STRENGTH

APPROVAL

THE STRESS CORROSION RESISTANCE AND THE CRYOGENIC TEMPERATURE MECHANICAL PROPERTIES OF ANNEALED NITRONIC 60 BAR MATERIAL

By
J. W. Montano

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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